Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

appearance due to the unequal reflection of light where the fibers run in different directions.

The structural phenomena discussed in the preceding paragraphs all furnish evidence tending to confirm the writer's theory of the origin of cross-fiber veins, and they are difficult or impossible of explanation under any other hypothesis of vein formation hitherto advanced.

Conclusions. Cross-fiber veins are formed through a process of lateral secretion, the growing veins making room for themselves by pushing apart the enclosing walls. The fibrous structure is to be attributed largely to the mechanical limitation of crystal growth through the addition of new material in only one direction. In the case of the asbestiform minerals the fibrous structure is accentuated by a normal prismatic habit and cleavage.

[1] The experiments herein referred to are described in my more extended paper on "The Genesis of Asbestos and Asbestiform Minerals" which will appear in an early number of *Bull. Amer. Inst. Min. Eng.*

[2] For a review of these theories, see Fritz Cirkel, Chrysotile asbestos, its occurrence, exploitation, milling and uses, Ed. 2, *Canada Dept. of Mines, Mines Branch, Report No. 69* (1910); O. B. Hopkins, A report on the asbestos, talc and soapstone deposits of Georgia, *Geol. Survey Ga., Bull.* No. 29 (1914); and J. A. Dresser, Preliminary report on the serpentine and associated rocks of Southern Quebec, *Canada Dept. Mines Geol. Survey Mem.* No. 22 (1913),

[3] Dresser, J. A., *Ibid.*, p. 65.

[4] Pratt, J. H., Asbestos, *U. S. Geol. Survey Mineral Resources*, 1904, pp. 1137–1140 (1905).

[5] Diller, J. S., Asbestos, *U. S. Geol. Survey Mineral Resources*, 1907, pt. II, pp. 720–721 (1908).

[6] Taber, Stephen, The growth of crystals under external pressure, *Amer. J. Sci.*, ser. 4, **41**, 532–556 (1916).

A NEW TEST OF THE SUBSIDENCE THEORY OF CORAL REEFS

By Reginald A. Daly

DEPARTMENT OF GEOLOGY AND GEOGRAPHY, HARVARD UNIVERSITY

Received by the Academy, October 27, 1916

According to Charles Darwin's much-discussed theory, a barrier reef represents the upgrowth of a coral reef which originally fringed a sinking (generally volcanic) island; and an atoll reef represents a further upgrowth, completed in typical form after the central island has sunk below sea-level. Between the upgrowing reef and the subsiding, central island is a concavity or 'moat.' Through the accumulation of detritus and shells and skeletons of organisms inside the reef, the moat is slowly filled. Above the detrital covering of the moat surface is the water of the 'lagoon.' The subsidence is supposed to have progressed until the deepest part of each moat has sunk scores, hundreds, or possibly thousands, of meters (see fig. 1).

The observed general flatness of the lagoon floors of atolls shows that there the hypothetical moats must have been completely filled and obliterated as distinct submarine forms. The depression occupied by the lagoon water inside each barrier reef has the position of the hypothetical moat, but in every case the lagoon floor is about as flat as an atoll-lagoon floor. For each kind of lagoon, therefore, the filling of the moat must be assumed to be far advanced. The inferred maximum depths of calcareous detritus are to be estimated in scores, hundreds, or possibly thousands, of meters. The mechanism of this filling has never been adequately discussed; yet its analysis cannot fail to indicate a valuable test of the subsidence theory of reefs. To the writer's knowledge, no earlier statement of the test has been published.

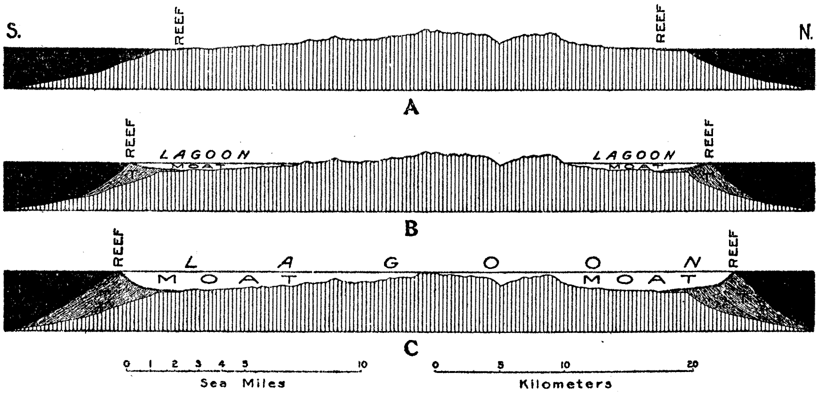

FIG. 1

Sections illustrating the subsidence theory as applied to the wider barrier and atoll lagoons; also illustrating the relations of moat, moat filling, lagoon, and central island. There is no exaggeration of the vertical element, and the depth of water in the deepest existing lagoons is no greater than that shown, to scale, by the width of the black line drawn below the word 'Lagoon.' Water indicated by solid black.

A. North-south section of the island of Kauai, chosen as a large, deeply eroded, volcanic island, which may be fairly presumed to typify the ancestor of one of the larger atolls, according to the subsidence theory. Fringing reefs indicated.

B. Section of the same island after subsidence, with the growth of each fringing reef (now become a barrier) upward and outward on its own talus (*T*). Between the reef and central island is the moat, the upper part of which is occupied by the water of the lagoon. The detrital filling of the moat is not shown.

C. Section of the same island after further drowning, with widening of the moat and ultimate development of an atoll.

The filling mechanism involves two factors: sediment, and active transportation of that sediment. Neither has been thoroughly discussed by Darwin or by any of his supporters; yet serious attention to both factors is the manifest, special duty of all those who advocate the subsidence theory.

Darwin stated that the filling of the concavity, here called a moat, is to be referred to "the growth of the delicately branched corals within the reef, and to the accumulation of sediment" (*The Structure and Distribution of Coral Reefs*, London, 2d ed., 1874, p. 132). He did not precisely indicate the nature or origin of the sediment. In part it is derived from the erosion of the central island, though at a rate rapidly diminishing as the island sinks; in part from the reefs, inner and outer; and in part from the remains of non-coral organisms, both free-swimming and bottom species. The rain of planktonic and nektonic shells and skeletons to the bottom will, of itself, be nearly uniform in the lagoon and not directly competent to obliterate the moat, until the lagoon is filled almost to sea-level. Modern field studies, like those at Funafuti, have shown that bottom lagoon organisms, including corals, are very largely restricted to depths less than 30 meters; that is, to shallows immediately adjoining the main reef, the coral knolls of the lagoon, and the shores of the central island, if present. In general the lagoon floor is 'sandy' and barren of growing coral. Dana held that the open-ocean waves throw into the lagoon, over the main reef, 'a large part' of the débris eroded from the growing, outer face of that reef. However, the detritus thrown over the main reef by waves of the open ocean is practically nil in all those cases where the reefs form dry land; and there are evidences, not here to be detailed, that the relative amount of lagoon sediment so added to the deposits in the average lagoon is actually small. The sediment brought into the lagoon through the occasional ship channels may be more important, but most of it is deposited, in delta form, just inside the main reef.

Thus, whatever be the various origins of the lagoon sediments, the detritus necessary to fill the hypothetical moat must be found principally in the shallower places within the lagoon. If the detritus were as fine as mud, its transfer to the deeper part of the moat might be comparatively rapid. Observation shows, on the other hand, that lagoon floors are characteristically more sandy than muddy, even in depths of 50 meters or more. Marine sand is transported on the bottom. It follows, then, that, if the floor of the hypothetical moat were carried down by subsidence to depths greater than those where waves and currents can stir bottom sands, the moat could be obliterated only after the detrital shelves, advancing from the shallows, have become confluent. Obliteration of the moat by this process is extremely slow for narrow lagoons, still slower for lagoons 20 to 50 kilometers wide.

Incidentally a question, not directly the subject of the present communication, arises. Is it possible to credit this explanation of all the hundreds of atoll lagoons, every one of which exhibits no trace of the hypothetical moat? The entire absence of moat concavities in the world's atolls and the correlated flatness of barrier lagoons can only mean prolonged crustal stability in the reef-charged areas.

The agents most responsible for the transportation of sediment into the depths of the hypothetical moat must be the waves and currents set going in the lagoon itself. The normal atoll or barrier reef, which reaches nearly or quite to sea-level, almost perfectly protects the lagoon from the powerful waves and currents of the open ocean. Some water is thrown over into the lagoon when great rollers break on low parts of the reef, with the effect of forming currents in the lagoon; but such currents cannot be other than weak. Tidal currents may be strong in narrow ship channels; inside the reef they are weak. The advance of detrital shelves, so as to fill the hypothetical moat, must, then, be very largely attributed to the activity of waves and currents originating in the lagoon. Except possibly during the rare hurricanes, these agents are incompetent to brush sand over the general bottom at the depths commonly ruling in atoll and barrier lagoons. But, assuming (in accordance with the hypothesis) that the transporting agents have been competent to fill the moats, an important effect on the form of the lagoon floor should be expected; the moat might in time be nearly filled, but *the lagoon floor should not be level.*

That feature ought to be found especially in lagoons situated in the trade-wind belts and not affected by monsoons or other strong winds from westerly quadrants. In these cases the lagoon waves and currents must set in a westerly direction, and chiefly in that direction sediment should be transported. Hence the hypothetical moat, like its existing lagoon remnant, should be filled at different rates on the windward and leeward sides respectively. According to the degree of enclosure of the lagoon by continuous reefs, the leeward part of its floor should now be higher or lower than the windward part. To use a technical expression, the lagoon area should be differentially aggraded. The same tendency ought to be seen in lagoons subject to variable winds, among which is a dominant system of winds blowing from one quarter of the compass.

To this reasoning it might be objected that back-running currents would reverse the direction of transportation for bottom débris. 'Banking' of water against the leeward section of the main reef would naturally cause return currents, if the reef were there continuous. Even in that case the currents must be comparatively feeble and unable to stir sand at depths of 40 or more meters. However, the leeward part of each atoll and barrier reef is usually discontinuous, the gaps in the reef wall being deep enough and wide enough to permit the ready escape of water blown thither by the wind. Hence, return or compensatory currents are not likely to be efficient in undoing the work of the direct, wind-driven waves and currents.

Consulting the charts and meteorological records, one finds scores of typical atolls located in belts where the trade winds cause the dominant waves and currents. The floor of each of these lagoons is strikingly level and not higher, more aggraded, either to leeward or to windward of the lagoon center. An example is the best known of all atolls, Funafuti, in the Ellice group of the Pacific (fig. 2). Funafuti has occasional strong winds from westerly quadrants, but records show the dominance of the trade winds. Since the main reef at Funafuti is continuous for long stretches on the leeward side, its lagoon should, according to the subsidence theory, be distinctly shallower there than on the windward side. The charted soundings, actually much more numerous than those entered in figure 2, demonstrate that the floor of the lagoon is nearly level and that the variations in depth have no systematic relation to the trend of the trade wind.

The lagoon floors of many other Pacific atolls, including those of the Marshall and Paumotu groups, show similar levelness. Most barrier lagoons of the Fiji and other archipelagoes in the trade-wind belts are also characterized by practically the same depths to windward and leeward of their respective central islands. Exceptional lagoons in the southwest Pacific have been shallowed or deepened, uniformly or differentially, by recent, local warpings of the earth's crust; in these instances the test cannot be applied with conclusiveness. Nor is it easily applied to the Maldives and neighboring atolls of the Indian ocean, where the monsoons change direction, through an angle of 180°, every few months.

Nevertheless, in spite of the quite special weather conditions required by the test, very many atoll and barrier lagoons are known to be favorably situated, and yet none shows systematic lack of symmetry in the submarine profiles crossing its lagoon from windward to leeward. So also are the cross-profiles of the windward and leeward reefs themselves respectively of the same quality. The windward reefs tend to be more developed, but their inner slopes are of nearly the same steepness as the inner slopes of the corresponding leeward reefs.

In conclusion, observed facts do not seem to agree with a legitimate deduction from the subsidence theory of coral reefs. On the other

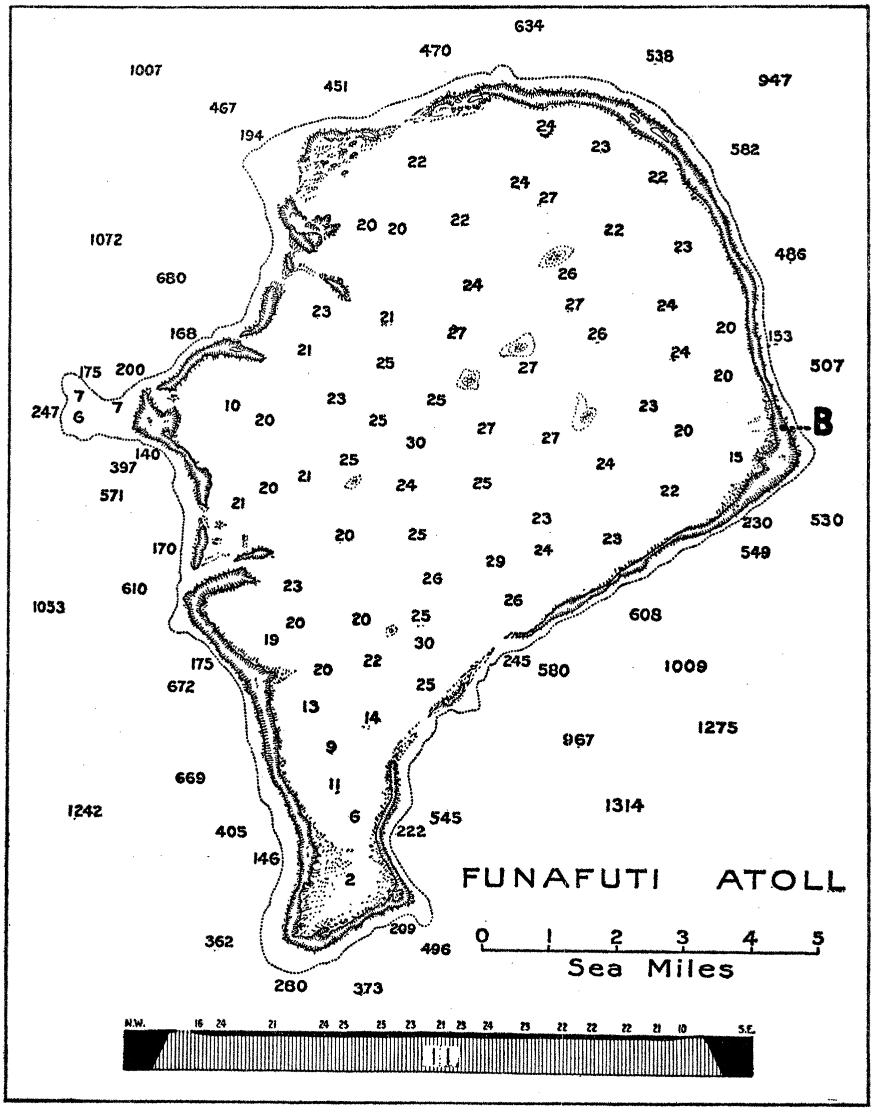

FIG. 2

Chart and section of the Funafuti atoll. Depths in fathoms (1 fm. is 1.83 m.). In the section water is shown in solid black; vertical scale three times the horizontal. The section is run near the middle of the atoll and in the general direction of the trade wind.

hand, a study of the symmetrical profiles of the reef-lagoon structures here considered has furnished one more direct indication that the existing coral reefs are new upgrowths on platforms, which have been formed before, and independently of, the reefs. The volumes of the reefs suggest that these began to grow not many thousands of years ago. The platforms, on which the reef crowns rest, seem to have been finally smoothed, and prepared as foundations, during the Glacial period. In any case, the submarine topography of each reef-platform structure *as a whole* and the elementary principles of oceanography together declare against the assumption that the forms and spatial relations of atoll and barrier reefs are due to the sinking of the earth's crust.

A NEW THERMOMETER SCALE

By Alexander McAdie

BLUE HILL OBSERVATORY, HARVARD UNIVERSITY

Received by the Academy, October 23, 1916

In the *Physical Review* (Vol. VI, No. 6, December, 1915), I urged the importance of adopting without further delay, in aerophysics, units that have a scientific basis. At Blue Hill Observatory for the past two years we have published summaries of air pressure also vapor pressure in *kilobars* or force units, temperature in degrees absolute centigrade, and wind velocities in meters per second. Wind direction is given in degrees, starting from the West; rainfall in millimeters and evaporation in force units.

The British Meteorological Office, under the progressive leadership of Sir Napier Shaw has published since 1915 results in similar units. Unfortunately the European definition of the megadyne atmosphere, the *bar* so-called, is misleading, a more scientific definition being *megabar*. The use of the smaller unit does away with the inconsistency of defining a millibar as 1000 bars, a self-evident contradiction, and allows us to define the bar, the basic unit as the force which would impart to a gram an acceleration of 1 cm. per second per second. A *kilobar* or 1000 bars becomes then the natural and consistent unit for all measurements of pressure in force units.

With regard to temperature, a concept all important in atmospherics, it is regrettable that we have no available method of expressing gain or loss of heat in terms of molecular motion. The ordinary mercurial thermometer is certainly a crude instrument and so far as thermometer scales go, there has been no real improvement since Linnaeus reversed the order of the Celsius marking. It will be generally conceded that